Lawrence Livermore National Laboratory

60 Years of Excellence

Science and Technology in the National Interest

FY2012 Annual Report

About the Cover:

Lawrence Livermore National Laboratory (LLNL) engineers Chris Spadaccini (left) and Eric Duoss are shown experimenting with direct ink-writing to create micro- to macroscale structures with extreme precision. The Laboratory is advancing this process and other additive manufacturing technologies to develop new materials with extraordinary properties for use in a wide range of national-security and other applications.

About the Laboratory:

Lawrence Livermore National Laboratory was founded in 1952 to enhance the security of the United States by advancing nuclear weapons science and technology. With a talented and dedicated workforce and world-class research capabilities, the Laboratory continues a tradition of science and technology innovation—anticipating, developing, and delivering solutions for the nation's most challenging problems.

The Laboratory is managed by Lawrence Livermore National Security, LLC (LLNS) for the National Nuclear Security Administration (NNSA), a semi-autonomous agency within the U.S. Department of Energy (DOE). LLNS is a limited liability company managed by Bechtel National, Inc., the University of California, BWX Technologies, Inc., and URS Energy & Construction, Inc. Battelle Memorial Institute also participates in LLNS as a teaming subcontractor. Cutting-edge science is enhanced through the expertise of the University of California and its ten campuses and LLNS' affiliation with the Texas A&M University system.

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What's Inside

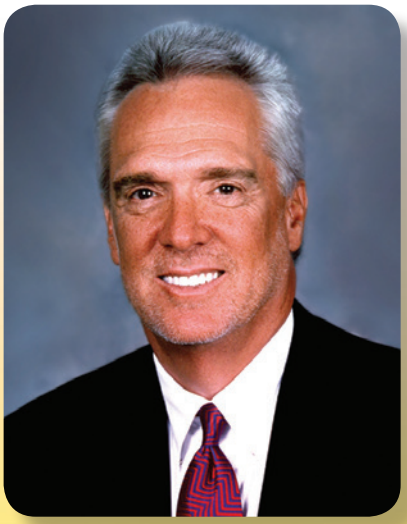
60 Years of Excellence

Cofounders Ernest O. Lawrence and Edward Teller.

Continuing a Tradition of Excellence

The laboratory at Livermore opened for business 60 years ago to meet an urgent national need. The Soviet Union had developed an atomic bomb more quickly than expected. The laboratory, now named Lawrence Livermore National Laboratory (LLNL), was established to accelerate work on innovative concepts for strategic and tactical nuclear weapons.

Penrose (Parney) C. Albright
LLNL Director and LLNS President



Norman Pattiz
Chair, LLNS Board of Governors

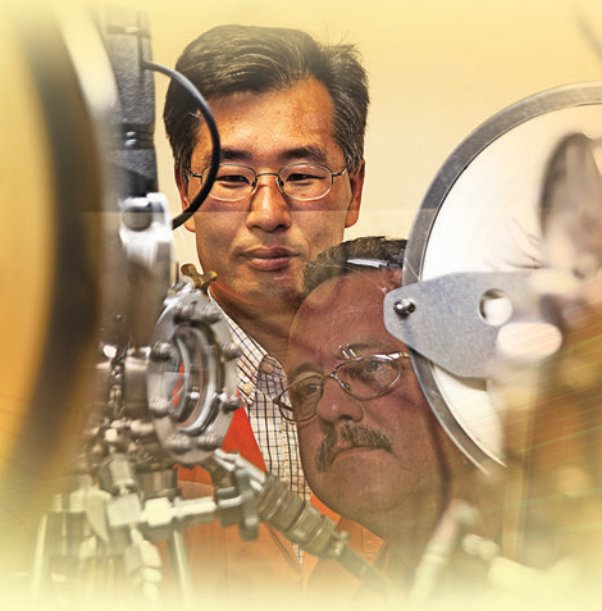
In two ways, Livermore was an experiment. Like the laboratory at Los Alamos, it was created as a new type of entity—a research institution managed as a federal–private partnership staffed with top-notch scientists and engineers to work on long-term nationally important problems. The establishment of Livermore also added the element of cooperative competition with Los Alamos to more rapidly develop nuclear weapons science and technology (S&T).

History has proved the experiment to be highly successful. Throughout the nuclear weapons era, Livermore and Los Alamos have provided key innovations in weapons effectiveness, safety, and security. Working with Sandia National Laboratories, they have met the demanding military requirements for the nation's nuclear deterrent.

Today, using very different approaches to nuclear design and engineering, the laboratories provide independent peer review of each other's work. In the absence of nuclear testing, these two centers of nuclear design expertise serve as a crucial safeguard in carrying out the U.S. policy to "sustain a safe, secure, and effective nuclear arsenal as long as nuclear weapons exist." This competition of ideas is complemented by cooperation—strengthened by the overlapping Board of Governors structure for Lawrence Livermore National Security, LLC (LLNS), and Los Alamos National Security, LLC (LANS).

The laboratories' long-term success speaks to the wisdom of managing these institutions through federal–private partnerships. The Department of Energy National Nuclear Security Administration's (DOE/NNSA's) national laboratories—Livermore, Los Alamos, and Sandia—are as essential as ever. These institutions provide outstanding S&T to address the wide range of security challenges facing our nation in the 21st century. They serve as broad national security laboratories, leveraging unique and peerless capabilities and expertise—all focused on their enduring mission.

Livermore set out to be a "new ideas" laboratory. Our heritage is the pursuit of innovative solutions to the most difficult national security problems using the multidisciplinary approach to large-scale science pioneered by cofounder Ernest O. Lawrence. Throughout the Laboratory's



In support of nuclear deterrence, LLNL is pursuing a life-extension program for the W78 intercontinental ballistic missile warhead. In addition, Laboratory researchers are conducting experiments and using the most advanced computers in the world to ensure confidence in our assessments of an aging stockpile. The experiments range from studying materials at extreme conditions using NIF (above) to examining the properties of aging plutonium (right) for assessing the longevity of nuclear weapon pits.

FY2012 Highlights

Expertise in HPC is central to many of our accomplishments. In FY2012, LLNL took delivery of the performance-record-breaking Sequoia supercomputer (shown being displayed to energy-industry research partners). In addition to its pivotal role in stockpile stewardship, HPC is being applied to improve seismic monitoring for nuclear events, assess climate change and its effects, and increase the competitiveness of U.S. industry through our HPC Innovation Center at the Livermore Valley Open Campus.

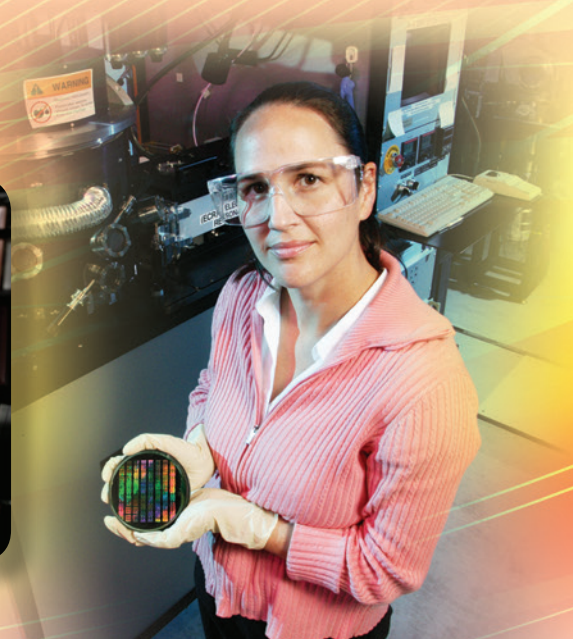
history, we have consistently explored new ideas and pushed back the frontiers of S&T in areas central to the success of our mission. Our innovation and science makes the nation safer.

Our annual report highlights the accomplishments by the exceptionally talented people at LLNL in fiscal year (FY) 2012. Our very challenging principal mission is sustaining the nation's nuclear deterrent without nuclear testing and countering nuclear proliferation and terrorism. In addition, LLNL applies cutting-edge S&T expertise to defense and international security areas such as advanced conventional munitions, biosecurity, cybersecurity, space situational awareness, directed energy weapons, and enhanced protection of soldiers. LLNL's unique expertise is also contributing to the nation's energy and environmental security and is being shared with U.S. industry to increase economic competitiveness.

LLNL's achievements in FY2012 are numerous. Yet our nation faces major challenges on many fronts in the years ahead. Advances in S&T are vital to continuing success in all mission areas. Notably, we must continue to rapidly upgrade high-performance computing (HPC) capabilities, achieve the grand challenge of fusion ignition at the National Ignition Facility (NIF), and apply our innovative S&T to an increasingly broad set of national-security sponsors. To succeed, the Laboratory is committed to providing an inviting workplace for exceptional people to work in the national interest and pursue cutting-edge research in a safe, secure, cost-effective, and an environmentally sustainable manner.

Anniversaries are an appropriate time to celebrate the past and embrace future challenges. It is also a time to thank Livermore's outstanding staff—past, current, and future—for their new ideas and dedicated hard work. Carrying on traditions established by the Laboratory's founders, we look forward to the next 60 years of excellence in mission-directed S&T, delivering innovative solutions in service to the nation.

LLNL's innovative advances in S&T are applied to a challenging array of national security issues. Breakthrough accomplishments include the development of two novel technologies for nuclear proliferation monitoring (neutron pillar detector shown below), mini-satellites for greatly improved tracking of space debris (below left), nanolipoprotein technology for vaccines against biological agents, and a new technique for more efficient desalination of seawater.



Nuclear Deterrence

Ensuring the safety, security, and effectiveness of the enduring stockpile

LLNL's foremost responsibility is to ensure the safety, security, and effectiveness of the nation's nuclear arsenal. Through experiments, theory, and simulations, researchers probe the underlying science of nuclear weapons and the effects of aging on weapon performance. They apply the knowledge gained to assess the condition of stockpile weapons, develop modifications as needed, and certify the implemented changes with confidence in the absence of nuclear testing.

Annual Stockpile Assessment

In FY2012, Cycle 17 of the annual stockpile assessment benefited from Livermore's continuing efforts to increase the rigor and quality of the process. The NNSA laboratories also jointly conducted the second cycle of the Independent Nuclear Weapon Assessment Process, which provided comprehensive peer review of each other's designed weapons. In support of this work, Livermore scientists made significant advances in three-dimensional simulation models used to assess performance and quantify uncertainties. They improved both physics fidelity and code performance, using historic nuclear test data and new experimental results for code validation. As an example, a major subscale hydrodynamics test in FY2012 provided data to validate and further improve a model of the detailed performance of the high explosive used in an LLNL stockpile system.

W78 Life-Extension Program

NNSA and the Department of Defense launched an option selection, detailed design, and costing study (Phase 6.2/6.2A) to extend the life of the W78 warhead on Minuteman III, which has aged beyond its planned service life. LLNL is the lead nuclear design laboratory for the Life-Extension Program (LEP). In addition to addressing aging concerns, Livermore weapons experts are evaluating options to incorporate enhanced safety and security features as part of changes that would be made to the warhead. Options are also being considered for interoperability of the nuclear explosive package with the U.S. Navy's W88 warhead as a hedge against unexpected issues arising in the stockpile.

Phase 6.2/6.2A follows completion of the LLNL/U.S. Air Force concept development study report (Phase 6.1) and a related NNSA W78/W88 120-day study. In support of these efforts and an Air Force-led Long-Range Stand-Off weapon study, Livermore developed a spectrum of nuclear-explosives-package design approaches and made significant progress on maturing technologies to enhance weapons manufacturability (to lower costs), surveillance, safety, and security. In particular, LLNL began work on a new explosive, executed pertinent hydrodynamic tests, and conducted a weapon-surety concept test in support of future LEPs.

Studded with outlets for fiber optical lines, the all-optical probe dome provided exceptional data about the uniformity of an implosion in a major subscale test.

Stockpile Stewardship Experiments

In 2012, LLNL's Joint Actinide Shock Physics Experimental Research (JASPER) facility at the National Nuclear Security Site in Nevada fired its 100th shot in a series of tests that have investigated the properties of plutonium shocked to extreme conditions. JASPER and other material-science experiments support LLNL studies of the effects of aging on plutonium pits. The latest results of accelerated-aging tests indicate no changes in 150-year-old plutonium that would affect weapon performance.

Laboratory scientists also successfully fielded three integrated weapons experiments at hydrodynamic testing facilities at Los Alamos and Livermore. One remarkable experiment performed at the Contained Firing Facility at LLNL's Site 300 tested the implosion of a subscale device, which required precision engineering. The test used an all-optical diagnostic, newly developed to collect copious amounts of data. In addition, stockpile stewards performed highly successful campaigns of groundbreaking high-energy-density experiments at NIF (see page 7).

Understanding the importance of high-performance computing to advancing nuclear weapons design, the Laboratory's founders ordered a Univac 1 before opening day. The machine performed nearly 2,000 operations per second. The Laboratory's drive for greater capability took its first step with the delivery of a 6-times-more-powerful IBM 701 in early 1954.

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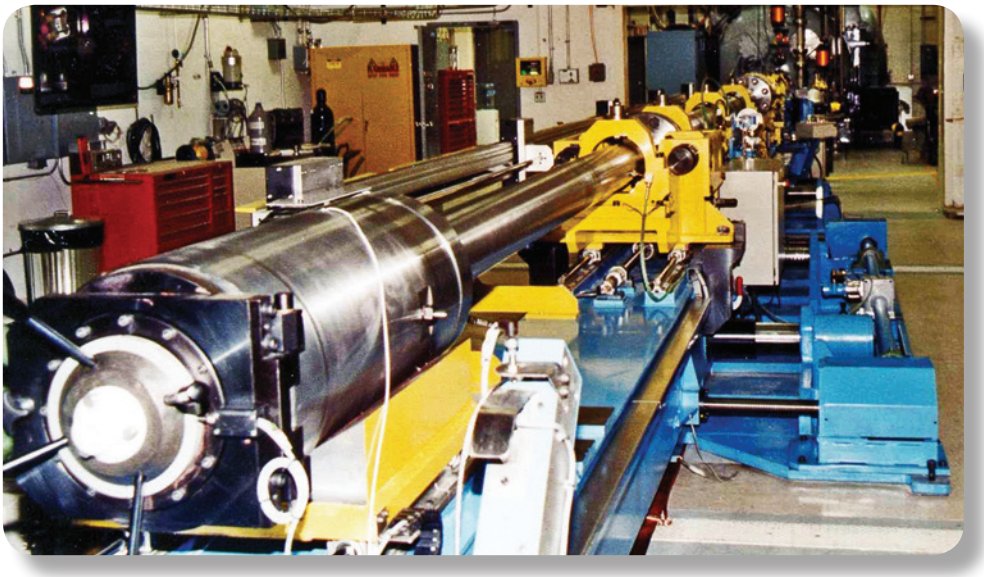


About 20 meters long, the two-stage gas gun at JASPER fired its 100th shot in FY2012, gathering data about the properties of plutonium at extreme conditions.

Sequoia and Beyond

Delivered this year to LLNL, the Sequoia supercomputer was honored by *Popular Mechanics* with the 2012 Breakthrough Award as a "world-changing" innovation. The IBM BlueGene/Q machine, which clocks 16.3 petaflops (quadrillion floating-point operations per second) on Linpack, was ranked as the world's fastest computer on the TOP500 list in June 2012. It is also ranked first on the Green500 list as the most energy efficient high-performance computer (HPC) and best by Graph 500 in its ability to solve "big data" problems. With 1.6 million cores working in parallel, Sequoia has demonstrated stunning capability in unclassified applications (see page 12). The machine will move to classified operations in 2013, running the most detailed weapon codes as well as large suites of simulations to quantify uncertainties.

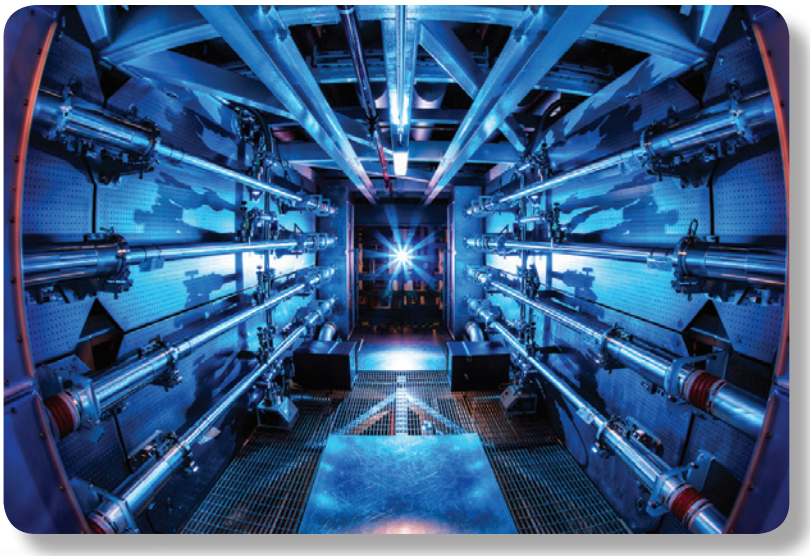
Also in FY2012, Livermore took the lead for NNSA and the DOE Office of Science in managing the FastForward Program to push HPC technologies toward the technically challenging goal of exascale (1,000-petaflops) computing. The request for proposals was formally released at the end of March, and in June, $62 million in research contracts were awarded to five leading HPC companies. Seven NNSA and DOE Office of Science national laboratories are partners in the FastForward Program.

A 96-rack IBM BlueGene/Q system with 1.6 million cores, Sequoia enables simulations that explore phenomena at a level of detail never before possible.

National Ignition Facility

Supporting stockpile stewardship, pursuing laser fusion ignition, and transitioning NIF into a national user facility for high-energy-density science

During FY2012, a total of 332 high-energy-density (HED) science experiments were conducted at NIF. These include 92 ignition and 26 nonignition experiments supporting the Stockpile Stewardship Program (SSP) and 10 experiments supporting fundamental science and other national security applications. With its record-setting laser performance, NIF is serving as a cornerstone of the SSP, providing valuable insights into the nature of the universe, and advancing the prospect of laser fusion as a carbon-free energy source.



NIF's preamplifiers are the first step in increasing the energy of lasers beams, which now deliver greater than 1.8 megajoules of ultraviolet light energy and 500 terawatts power with the precision required for ignition experiments.

Stellar Laser Performance

On July 5, 2012, the NIF team conducted a record-breaking laser shot. NIF's 192 laser beams delivered 1.85 megajoules of ultraviolet light energy and 522 trillion watts of peak power to a target with a precision ignition-relevant pulse shape. The pulse was 1,000 times more power than the United States uses at any instant and 100 times more energy than any existing laser routinely produces. This shot demonstrated that NIF has met or exceeded all of its specifications and performance requirements.

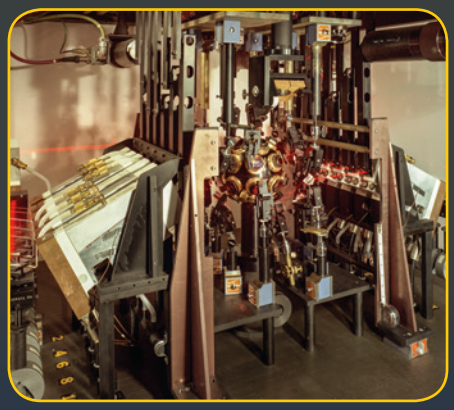
NIF senior technologist Leslie Allison inspects a laser mirror line replaceable unit being readied for refurbishment. Remarkable improvements in the damage resistance and refurbishing time of critical optical components enable routine use of the laser at very high levels of energy and power.

By creating conditions of extreme temperature, pressure, and density never before possible, NIF is proving to be a remarkably reliable, precise, and flexible tool for conducting HED science experiments. Nearly 60 major diagnostics are now in place and acquiring high-quality data for the wide range of different types of experiments performed by the NIF team working with collaborators.

Progress toward Ignition

While the grand challenge of demonstrating fusion ignition and burn has yet to be attained, LLNL and its partners in the National Ignition Campaign (NIC) made enormous scientific progress toward the goal. In support of the NIC, researchers have achieved—or are close to achieving—ignition-point-design values for many of the conditions required for ignition. These include the temperature of the hohlraum (which creates the x rays that implode the target capsule), the velocity of the imploding capsule and its symmetry, the temperature of a hot spot of deuterium–tritium fuel (where ignition is to occur), and the density of the cold fuel surrounding the hot spot (as measured by areal density).

Scientists at NIF have increased the fuel pressure by more than a factor of 10 in the last year to 150 billion atmospheres, only a factor of two to three away from that needed to achieve ignition and fusion burn. Continuing efforts are directed at targeted physics experiments and integrated experiments using a cryogenically cooled layered target with deuterium–tritium fuel. Specially designed targets for the physics experiments gather data for



In 1960, the concept of inertial confinement fusion arose at Livermore nearly coincidently with the invention of the laser. Livermore researchers quickly realized the potential utility of the new technology. By the mid-1960s, they were using the 12-beam “4 Pi” multigigawatt ruby laser system to study plasma temperatures and ion emissions from irradiated targets.

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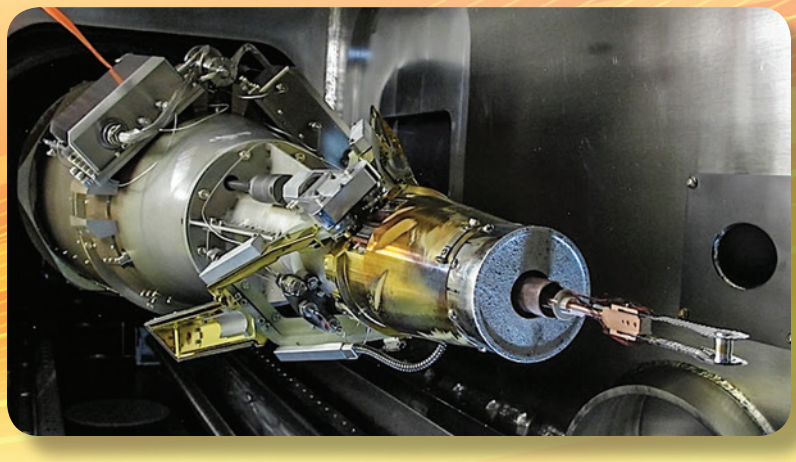
In the NIF control room, physicist Hye-Sook Park and target area coordinator Shawn Van Tol align the Velocity Interferometer System for Any Reflector (VISAR) diagnostic, widely used for high-energy-density and fusion ignition experiments.

scientists to better understand and reduce hydrodynamic instabilities, improve the fuel shape, and enhance implosion dynamics. The campaign is benefiting from NIF’s exceptional laser performance and the superb capabilities at LLNL and its collaborators around the nation and the world to meet demanding schedule requirements for the wide array of high-precision target and diagnostics used at NIF. Experimental data are being used to improve and validate the physics models in the simulation codes used to guide further experiments.

HED Science Experiments

As part of the SSP Materials Campaign, LLNL conducted a series of 10 shots collecting data to characterize tantalum’s material strength and equation of state at more than 10 million times Earth’s atmospheric pressure (10 megabars). In addition, for the Pleiades campaign, researchers from Los Alamos National Laboratory and the United Kingdom’s Atomic Weapons Establishment conducted experiments to study how radiation in the form of x rays interacts with matter. Focused on the physics of stellar environments, these shots explore how radiation burns through low-density foam subjected to temperatures of 3 million degrees. Other platforms are being developed to acquire data in experiments using higher density materials.

In support of fundamental science, a team of academic researchers collaborated with LLNL scientists to determine the equation of state of carbon at nearly 50 megabars. They applied the same techniques as used in the tantalum experiments. A first equation-of-state experiment has also been conducted for iron. This team’s interest is the formation and structure of large planets, such as Jupiter and Saturn.



A tritium-filled target, assembled and aligned on the cryogenic target positioner, is readied for an ignition campaign experiment to study implosion hydrodynamics.

NIF as a User Facility

At the end of FY2012, NIF transitioned to a user facility supporting all mission areas. NIF is attracting researchers from NNSA and DOE Office of Science national laboratories, other federal agencies, academia, the private sector, and the international scientific community. More than 170 attendees representing 16 different countries participated in a very successful NIF User Group meeting in February 2012, and a second NIF User Group meeting is scheduled for February 2013. An Experimental Facilities Committee (EFC) met several times in FY2012 to review shot requests and allocate NIF facility time across mission areas. The NIF Governance Plan, issued by NNSA in October 2012, describes the role and responsibilities of EFC, the peer-review processes, and the NIF management team.

Global Security

Providing expertise and systems solutions to counter proliferation, defend against terrorism, support the U.S. military, and enhance global stability

LLNL applies the full spectrum of its capabilities to pressing issues affecting global security. Researchers develop advanced technologies to preclude the proliferation or use of weapons of mass destruction and to enhance the capabilities of the U.S. military. Technical experts support international engagement in nonproliferation, threat reduction, and nuclear test monitoring, and innovations in space situational awareness and cyberdefense help strengthen national security in an interconnected world.

Lab Directors Visit Russia

A successful U.S.–Russia Laboratory Directors Meeting was held in Sarov, Russia, in June 2012. The meeting supported the U.S. government's goal of improving cooperation through S&T. The meeting and associated tours of five Rosatom laboratories provided an opportunity for the U.S. and Russian directors and representatives of Rosatom and NNSA to establish a path forward for scientific and technical cooperation in basic S&T, international security, energy research, and other areas of mutual interest.

Laboratory directors Charlie McMillan (Los Alamos), Parney Albright (Livermore), and Paul Hommert (Sandia) talk with Arkadiy Brish, one of the designers of the first Soviet atomic and hydrogen bombs, at the All-Russian Research Institute of Automatics, in Moscow.

Treaty Verification and Monitoring

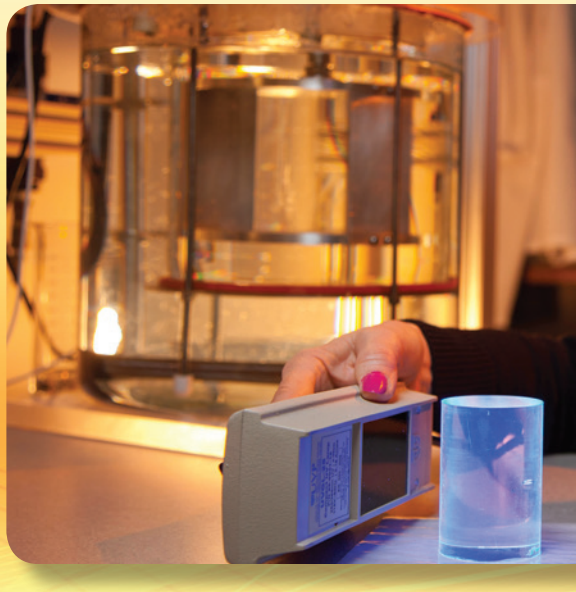
Effective verification of nuclear nonproliferation and test-ban treaties requires the ability to discriminate between legitimate and weaponization activities. LLNL led the modeling and data analysis for the Pele test that assessed the ability of various technologies to discriminate signatures of weapon development activities from other pursuits. The results from this test campaign will help determine which techniques can be used for treaty verification and monitoring.

LLNL continued to provide technical support to the Comprehensive Nuclear-Test-Ban Treaty Preparatory Commission (CTBT PrepCom) for developing an on-site inspection regime. The effort included fieldwork to test technologies for detecting radionuclide and geophysical signatures of nuclear explosions and to assess their suitability for use in on-site inspections. A Laboratory scientist also continued to lead the CTBT PrepCom Working Group B for implementing the International Monitoring System.

In addition, the Laboratory developed and implemented innovative computational models for seismic wave propagation. This work is part of a new paradigm for seismic nuclear explosion monitoring that uses LLNL's supercomputing capabilities and advanced three-dimensional Earth models developed in collaboration with the academic community.

New Materials for Neutron and Gamma Detection

LLNL scientists developed the first plastic scintillators that can detect and differentiate neutron and gamma radiation (which is key to identifying uranium and plutonium and distinguishing them from other radioactive sources). Impressively, the plastic scintillators perform almost as well as the standard detection materials. The manufacturing process is much safer, more flexible, and more environmentally friendly than the process for stilbene, while the gamma-detecting scintillator offers performance approaching that of sodium iodide but at much lower cost. The combination of efficient pulse-shape discrimination, low-cost fabrication, and ease of deployment makes these new



LLNL materials scientist Natalia Zaitseva led a research team that developed the first plastic material capable of efficiently distinguishing neutrons from gamma rays, something not thought possible for the past five decades or so.

In 1957, Livermore conducted the first underground nuclear test. The Rainier event was announced so that remote seismic stations could attempt to record a signal. The test provided scientists an understanding of underground explosion phenomenology and the basis for later decisions to halt atmospheric testing and deploy an international array of seismic detectors to monitor testing activities.

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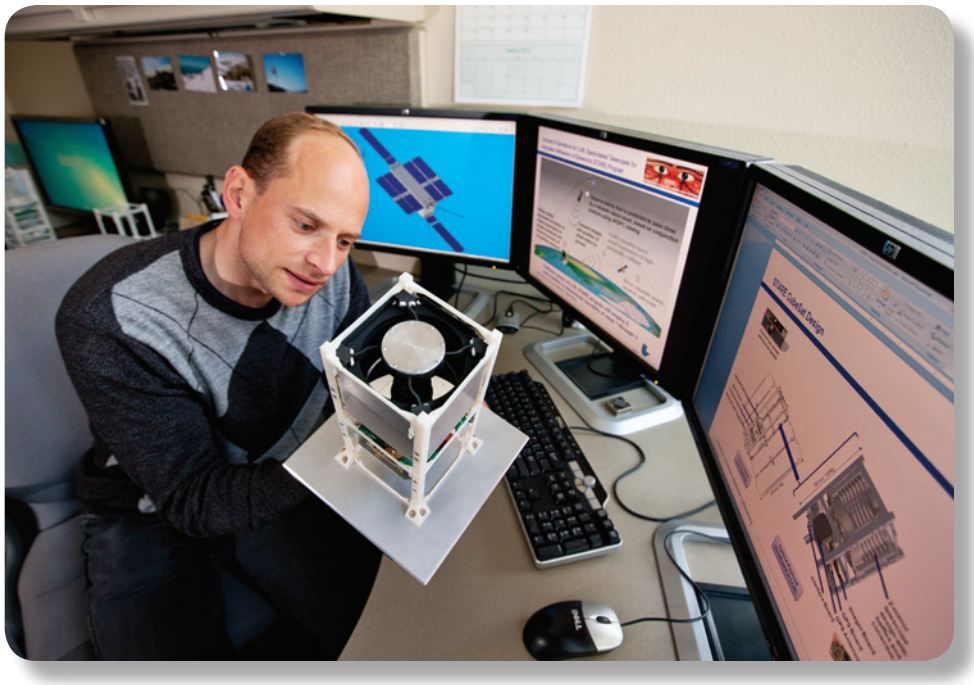


Engineer Vincent Riot holds the STARE flight optical payload in its handling fixture. STARE is a three-unit cube satellite (each unit measuring 10 centimeters on a side) for greatly enhanced monitoring of space debris.

scintillator materials ideal for use as large-area detectors in ports, stadiums, and other such facilities.

LLNL researchers also dramatically improved and reached nearly 50 percent efficiency in a novel technology they developed for detecting thermal neutrons from plutonium shielded to evade detection (see image on page 3). Instead of requiring scarce helium-3, as is required with current thermal neutron detectors, the new technology uses narrow pillars of silicon etched on a wafer and coated with boron. Partners are now being sought to commercialize this detector technology.

RIMS for Nuclear Forensics

Resonance ionization mass spectrometry (RIMS), developed originally to study grains of stardust recovered from meteorites, was successfully demonstrated as a potential nuclear forensics tool with the ability to rapidly and accurately measure isotopic ratios of uranium and plutonium. Unlike conventional mass spectrometry, which cannot distinguish between different isotopes of identical mass (e.g., uranium-238 and plutonium-238) in the same sample, RIMS uses lasers to excite each selected element. When the lasers are tuned to excite plutonium, the uranium signal is essentially absent and when the lasers are tuned to excite uranium, the plutonium sign is absent. Thus RIMS can measure the isotopic ratios of both actinides in the same sample, with virtually no sample preparation. Results can be obtained in only a few hours.

Tracking Space Debris

A three-unit cube satellite called STARE (Space-Based Telescopes for Actionable Refinement of Ephemeris), launched on an Atlas V rocket in September, contained a Laboratory-designed optical payload for tracking pieces of space debris with a precision 10 times greater than currently possible, resulting in a false alarm rate 100 times lower than present capabilities. Telescope, cameras, attitude control, data transmission, power, and GPS were all packed into a 10- by 10- by 30-centimeter space. LLNL also developed the algorithm that detects the debris tracks from end point to end point as well as the firmware that runs the payload processor; acquires the GPS location, time, and images; and runs the tracking algorithm on the images.

Energy and Environment

Using science and technology to meet the need for clean abundant energy, protect the environment, and understand and mitigate climate change

Laboratory researchers apply leading-edge scientific, engineering, and computational capabilities to develop efficient and environmentally benign energy technologies and to investigate the processes that drive climate change.

New Catalyst for Capturing CO_2

An LLNL team developed a new catalyst that can separate carbon dioxide (CO_2) from the flue emissions of coal-fired power plants. The molecule mimics the action of carbonic anhydrase, the enzyme that captures and transports CO_2 as part of the normal respiration process in humans. LLNL supercomputers were used to perform quantum molecular calculations to determine optimal designs for the catalyst. The most promising structures were synthesized and tested in the laboratory to determine their kinetic behavior and stability. The best one, called Cyclen, is now being tested in an industry setting to measure its industrial kinetics and determine how to integrate it into power plant processes.

LLNL chemist Carlos Valdez is shown synthesizing molecules proposed by the computational team. The best candidate for CO_2 capture is now being tested in an industry setting.

Snowflake Power Divertor

A key problem for a commercial-scale magnetic fusion tokamak is distributing the hot plasma exhaust over a sufficiently large wall surface area. Existing techniques divert the heat flux to specially designed plates, but the projected power density of a commercial tokamak is well beyond the heat capacity of current materials. The Snowflake Power Divertor, developed by an LLNL scientist and collaborators, spreads the plasma exhaust over a larger wall area and reduces the heat flux to manageable levels. The divertor has demonstrated large heat-flux reductions in tokamaks at the Princeton Plasma Physics Laboratory and the Center for Research in Plasma Physics (Lausanne, Switzerland). Several facilities under design are also planning to use the new divertor.

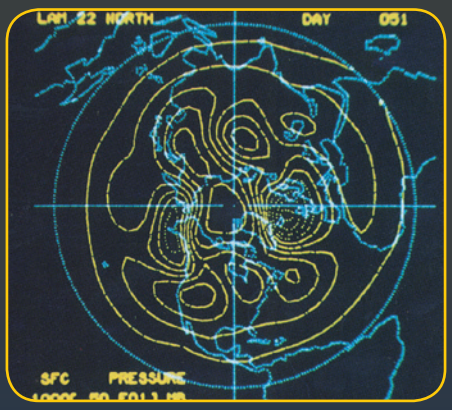
HPC Energy Collaborations

The Laboratory entered into a project with the California Energy Commission to leverage LLNL's HPC capabilities and high-resolution weather models. This effort aims to improve the forecasting of solar and wind power generation and to address some of the system-level challenges involved in integrating intermittent renewable energy sources into the state's energy grid. LLNL also launched the "hpc4energy incubator," a pilot program that teams industry with the Laboratory's scientific and HPC resources to find solutions to pressing energy-related problems of mutual interest. Six companies (GE Energy Consulting, Robert Bosch LLC, Potter Drilling Inc., ISO New England, United Technologies Research Center, and GE Global Research) are collaborating with Livermore scientists and using the Laboratory's computing resources to accelerate the development of energy technologies. At a workshop in November 2012, company representatives highlighted how HPC is showing them exciting ways "to think differently about problems." LLNL's HPC Innovation Center provides a focal point for work on the projects.

Shrub Height and Arctic Climate

Modeling of climate system feedback by LLNL researchers and collaborators revealed that as shrubs colonize tundra

In a vertical cross-section of a tokamak, the exhaust plasma exhibits broad spreading (left) due to the snowflake-shaped magnetic field lines (right) with six branches (counting the two directed upward) near the magnetic null (double cross).



With expertise in atmospheric science at first supporting nuclear testing activities, Livermore researchers applied weapons-design coding techniques to build the first global circulation model in the late 1950s. Simulation results were displayed in a movie of the behavior of large weather systems in the Northern Hemisphere (viewed from the North Pole).

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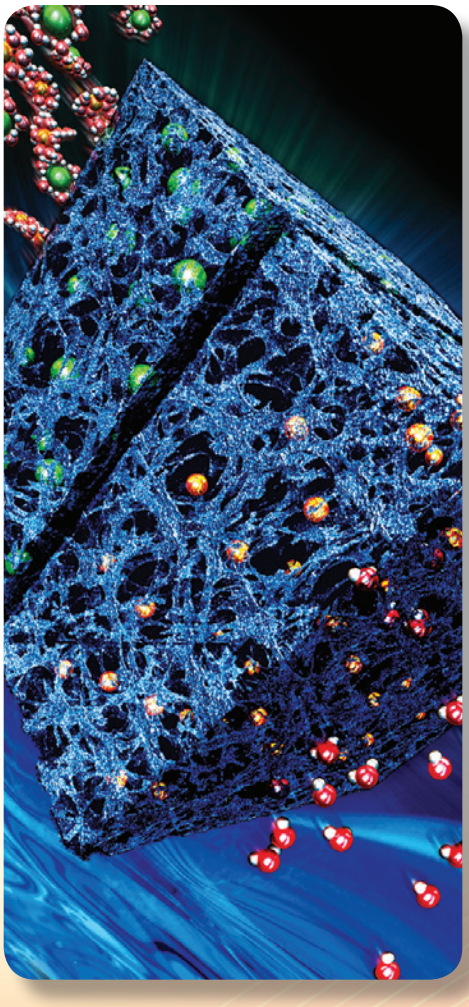
ecosystems in the future, they will likely have a notable warming effect. As shrubs invade the permafrost, they absorb sunlight and release water vapor due to transpiration. This process warms the area and increases permafrost melting, which releases greenhouse gases (mostly CO_2 and methane) that contribute to further warming. A 20 percent increase in shrub cover above 60°N latitude is projected to lead to an annual temperature increase of 0.66°C if the shrubs are 0.5 meters tall and 1.84°C if they are 2 meters tall. Taller plants lead to larger temperature increases because they stick out above the snow and absorb sunlight over the entire year, whereas short plants are covered for part of the year by snow (which reflects sunlight).

Separating Climate Signal and Noise

LLNL scientists analyzed satellite measurements of the temperature in Earth's lower troposphere (from the surface to about five miles above) and saw a clear signal of human-induced warming of the planet. Satellite measurements of atmospheric temperature are made with microwave radiometers and are completely independent of surface thermometer measurements, whose reliability has been questioned by some climate change skeptics. The satellite data indicate the lower troposphere has warmed by roughly 0.5°C since the beginning of satellite temperature records in 1979, an increase that is entirely consistent with the warming estimated from thermometer records. The study also showed that temperature records must be at least 17 years long to separate a slowly evolving human-caused global warming signal from the noise of purely natural climate fluctuations.

Flow-through electrode capacitive desalination uses a new hierarchical porous carbon material with the feed stream passing directly through the electrodes to significantly improve salt removal and desalination rate.



Novel Desalination Technique

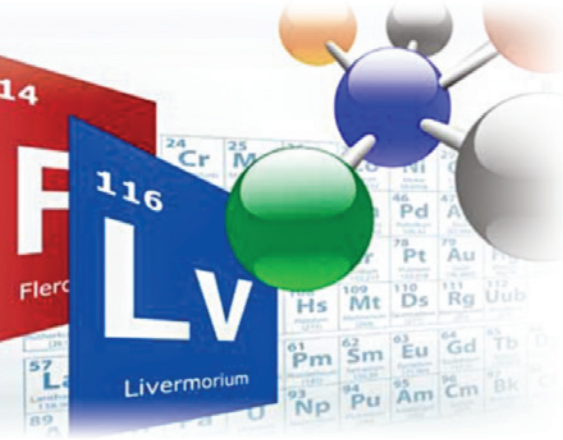
LLNL researchers developed a novel technique for purifying seawater. Flow-through electrode capacitive desalination (FTE-CD) uses new porous carbon materials that allow the saltwater to easily flow through the electrodes (instead of between them, as in traditional CD). The improved technique results in faster desalination, greater salt removal per capacitor charge, increased energy efficiency, and decreased cost. FTE-CD can desalinate brackish water in a single step and seawater in an energy-efficient multistage process.

National Oceanic and Atmospheric Administration (NOAA) satellites provide measurements of atmospheric temperature. Data clearly indicate that the lower troposphere is warming. (Courtesy of NOAA.)

Science and Technology

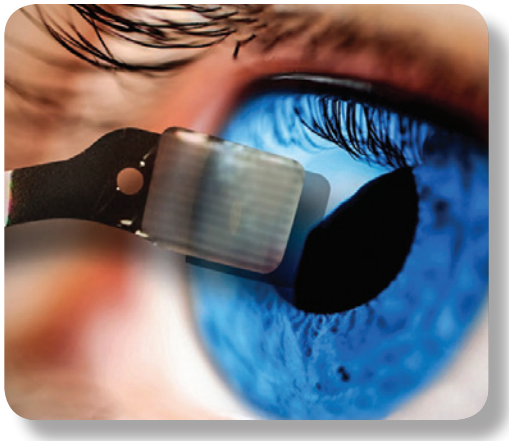
Expanding the boundaries of scientific knowledge and advancing the technological state of the art to solve problems of national and global importance

Science and technology are central to solving many of the most serious problems of the 21st century and to understanding the world around us. Research using LLNL's world-class experimental and computational resources and multidisciplinary scientific expertise has led to an array of exciting discoveries and innovations.



Livermorium

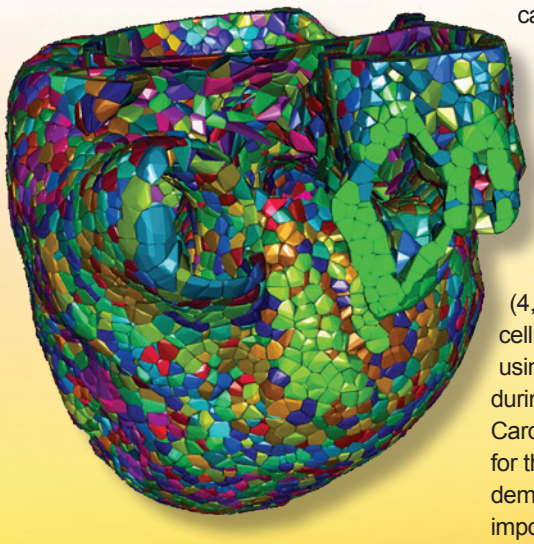
The International Union of Pure and Applied Chemistry (IUPAC) officially approved the name livermorium (Lv) for element 116 to honor LLNL and the city of Livermore. Researchers from LLNL and the Flerov Laboratory of Nuclear Reactions, in Dubna, Russia, have created a total of six new superheavy elements (elements 113–118). The IUPAC stated that livermorium was chosen because scientists at Livermore have been responsible for major advances in many areas of nuclear science. The IUPAC also accepted the name flerovium (Fl) for element 114, chosen to honor the Flerov Laboratory and its founder, Georgi Flerov.



The use of novel materials and LLNL advances in nano- and microfabrication techniques make possible implantable, biocompatible devices for long-term use, such as retinal prosthesis.

Human Heart Simulation

LLNL's Sequoia supercomputer was used to develop a groundbreaking code, called Cardioid, for simulating the electrophysiology of the human heart. Developed by Laboratory scientists and colleagues at the IBM Watson Research Center in New York, the code accurately simulates the activation of each heart muscle cell and the cell-to-cell electric coupling. Simulating an hour of heart activity (4,000 to 5,000 heartbeats) at nearly cellular spatial resolution takes seven hours using the full Sequoia system. Conducted during Sequoia's "shake down" period, the Cardioid simulation, which was a finalist for the 2012 Gordon Bell Prize, clearly demonstrated the power of HPC to address important issues beyond national security.



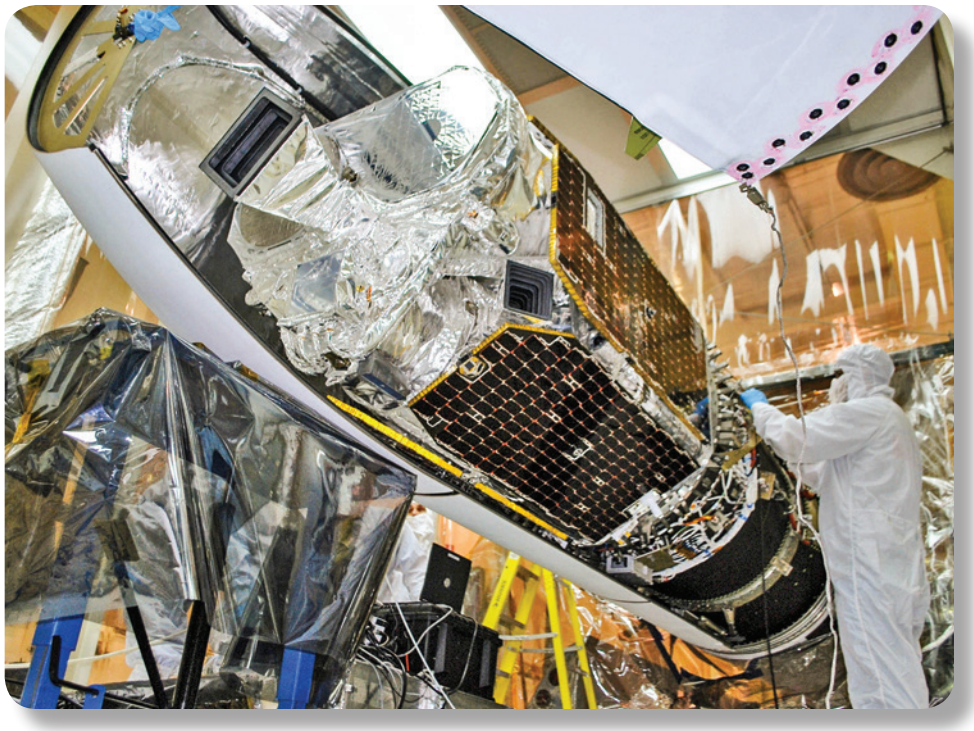
Simulations were performed with near-cellular resolution to determine the potential effect over time of an administered drug on the functioning of a human heart.

Neural Implants

Laboratory researchers made great strides in developing a new class of neural implants. The LLNL microelectrode arrays are embedded in a flexible, thin film polymer, allowing them to move naturally and conform to the live tissue in which they are implanted. The electronics and power for the device are hermetically sealed in a biocompatible package that measures a mere 10 millimeters in diameter and 4 millimeters tall. This platform technology has enabled the development of the world's first retinal prosthesis, which has U.S. Food and Drug Administration and CE (Conformité Européene) approval for implantation into human patients to restore sight. In addition to a third-generation 240-microelectrode retinal prosthesis, the LLNL team is developing an auditory nerve implant with hundreds of electrodes (vs. 19 in the most advanced cochlear implant). Other efforts include implants to treat Parkinson's disease via deep brain stimulation and to provide nerve prosthesis for restoring function (e.g., bladder control) after various types of injuries.

60 Years of Excellence

In 1963, the Laboratory launched a biomedical research program and before the end of the decade scientists were applying their computational expertise to study biology. Researchers developed a system called CYDAC that used electron microscope data to "see" each chromosome as 100,000 bits of information, allowing abnormalities in chromosomes to be spotted.



Technicians at Vandenberg Air Force Base in California prepare for the launch of the Orbital Sciences Pegasus XL rocket that carried NuSTAR into orbit. (Courtesy of NASA.)

Nanolipoprotein Vaccines

LLNL and Loyola University were awarded a five-year grant from the National Institutes of Health to develop a new anthrax vaccine based on LLNL's breakthrough nanolipoprotein (NLP) technology. Laboratory researchers have successfully used this approach to produce a candidate West Nile Virus vaccine. Additional work is under way to develop NLP-based vaccines for several other bioagents of concern. Because the method uses recombinant DNA technology to create vaccine candidates from specific pathogen genes, vaccines could potentially be developed against hundreds of diseases. In addition, because NLPs can be dehydrated to form a stable powder, stored for months at room temperature, and then rehydrated, NLP vaccines are ideal for field inoculation or use in developing countries.

Purna Venkataraman, while a summer student at LLNL, prepares samples to be used in tests on the nanolipoprotein platform.

Instruments for X-Ray Astronomy

LLNL contributions were integral to two new National Aeronautics and Space Administration (NASA) satellites launched this year. Laboratory researchers played key roles in the design and testing of the x-ray optics for the Nuclear Spectroscopic Telescope Array (NuSTAR), which was launched in June. With more than 10 times the resolution and over 100 times the sensitivity of any previous hard-x-ray instrument, NuSTAR will enable researchers to see extreme objects that have never been seen before, such as the black holes that are believed to exist at the center of all galaxies. Another LLNL researcher played a critical role in developing the Cosmic X-Ray Background Nanosatellite (CXBN), modeling the performance of the satellite's cadmium-zinc-telluride x-ray detector and writing the control software that moves the spacecraft. Launched in August, CXBN is designed to provide an improved measurement of the universe's x-ray background, which comes from all directions in space, to help identify the origin of that background.

Insights about Exoplanets

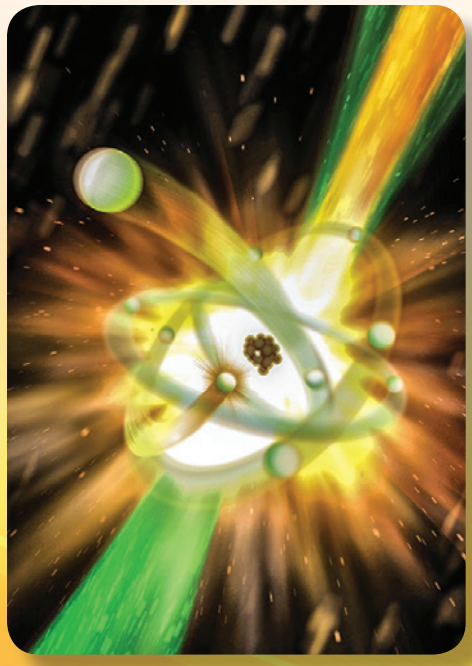
Livermore scientists were part of several international teams that made exciting discoveries about exoplanets. Analysis of gravitational microlensing data indicated that planets around stars in our galaxy are the rule rather than the exception. The researchers found that approximately 17 percent of stars in the Milky Way galaxy have Jupiter-mass planets, 52 percent have cool-Neptune-like

planets, and 62 percent have super Earths. These data are consistent with every star in the Milky Way hosting one or more planets with orbits in the range of 0.5 to 10 Sun–Earth distances.

Laser facilities at LLNL were used to study the structure of exoplanets. Experiments at NIF provided equation-of-state data for materials relevant to exoplanet compositions at pressures far greater than possible with other techniques. These results are being incorporated into the models used to interpret exoplanet structure (see page 7). Other research was conducted using Livermore's Janus laser and the University of Rochester's OMEGA laser to study the behavior of silicate magmas at extreme temperatures and pressures. Scientists found that the material undergoes a phase transition, a phenomenon that may help explain the thermal–chemical evolution of exoplanet interiors.

New Atomic X-Ray Laser

Laboratory scientists and international collaborators created the shortest, purest x-ray laser pulses ever achieved. The researchers aimed radiation from the Linac Coherent Light Source (LCLS), located at the SLAC National Accelerator Laboratory, at a target containing neon gas, setting off an avalanche of x-ray emissions that created the first-ever atomic x-ray laser. This work represents a major advance in the quest for shorter wavelength lasers and provides a very sensitive test of the physics of intense x-ray interaction with atoms.



A powerful x-ray laser pulse from the Linac Coherent Light Source comes up from the lower-left corner (green) and hits a neon atom (center). (Courtesy of SLAC National Accelerator Laboratory.)

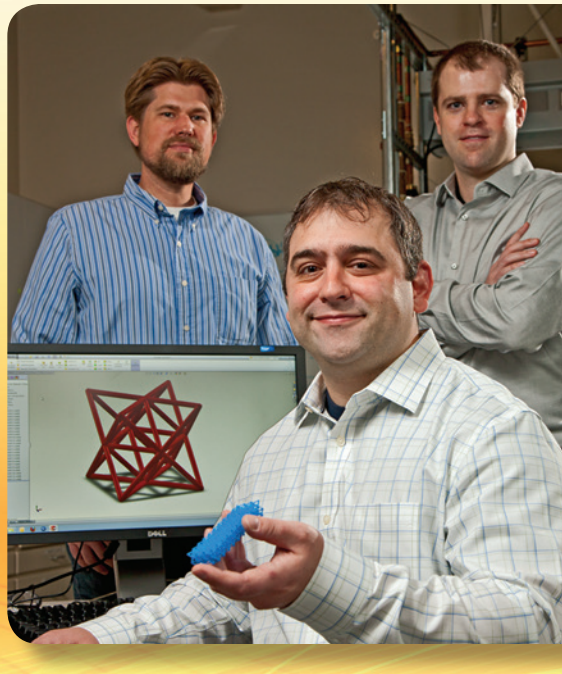
Deep Computing Solutions

Building on two decades of collaboration in HPC, LLNL and IBM formed the Deep Computing Solutions alliance, in which experts from the two institutions will work with industry collaborators to devise HPC solutions for accelerating the development of new technologies, products, and services. Areas of interest include applied energy, green technology, biology, materials, manufacturing, data management, and informatics. Projects will make use of the Laboratory's new 5-petaflops Vulcan supercomputer (a 24-rack IBM BlueGene/Q system). The collaboration will be conducted under the aegis of LLNL's HPC Innovation Center.

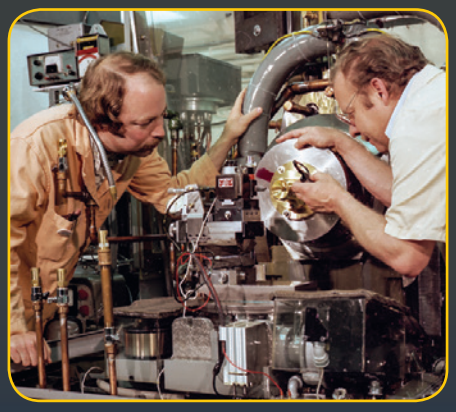
Additive Manufacturing

The Laboratory launched a major new research and development program in additive manufacturing. By this process, three-dimensional structures are created from the inside out by sequentially depositing materials layer by layer with extreme precision until the desired shape is complete. LLNL scientists and engineers developed prototype additive micromanufacturing equipment to fabricate three-dimensional microstructures with submicrometer features. By controlling the microstructure of a component, materials can be designed and produced with previously unobtainable properties (e.g., high stiffness together with low density). LLNL also helped organize a symposium in Washington, D.C., to engage U.S. policy and research leaders in dialogue about this disruptive technology and its implications for national security and economic competitiveness.

Using the Vulcan computer (detail shown), experts from IBM and LLNL will work with American industry to accelerate the development of new technologies, products, and services.



60 Years of Excellence



In 1955, Livermore established a precision engineering group to meet the needs of the weapons program—better determining and correcting for the sources of error in measuring instruments and machine tools. By the 1960s, engineers developed the world's first numerically controlled diamond turning machine (DTM-1), with 40-millionth-of-an-inch repeatability. The more capable DTM-2 (shown) was commercialized in the 1970s.

Entrepreneurs Hall of Fame

Fifteen former LLNL scientists and engineers were inducted into the Laboratory's new Entrepreneurs Hall of Fame. The inductees were: Jim Bryan (precision machining), Brent Dane and Lloyd Hackel (laser peening), Mike Farmwald (computer memory), Joe Gray and Dan Pinkel (chromosome painting), John Hallquist (LS-DYNA), Tom McEwan (micropower impulse radar), Bruce McWilliams (semiconductor technologies), Tom McWilliams, Curt Widdoes and Jeff Rubin (SCALD), Allen Northrup (rapid PCR), Robert Parker (liquid crystal technology), and Walter Scott (digital Earth imaging). Together, these innovators have launched several new industries, started nearly two dozen companies, and brought more than 50 commercial products to market.

LLNL materials scientists and engineers Joshua Kuntz, Chris Spadaccini, and Eric Duoss are developing additive manufacturing techniques for designing and creating new materials with extraordinary macroscale properties.

Technology Awards

LLNL received six R&D 100 Awards in 2012. The Laboratory was the principal developer in four of the awards: the High-Velocity Laser-Accelerated Deposition (HVLAD) process for producing protective coatings that can withstand extreme environments, the LEOPARD (Laser Energy Optimization by Precision Adjustments to the Radiant Distribution) system for precisely adjusting a laser beam's intensity profile, the first plastic scintillator material capable of efficiently distinguishing neutrons from gamma rays (see page 8), and the Snowflake Power Divertor for magnetic fusion reactors (see page 10). The two other awards were joint submissions: a portable Multiplexed Photonic Doppler Velocimeter (with National Security Technologies, LLC) that simultaneously measures up to 32 discrete surface velocities onto a single digitizer, and NanoSHIELD (with Oak Ridge National Laboratory, Carpenter Technology Corporation of Bridgeville, Pennsylvania, and the Colorado School of Mines), a supertough coating that is harder than tungsten carbide–cobalt composite but costs half as much.

Glassy alloy powder is delivered onto a metal substrate and fused with it using lasers to form a superhard NanoSHIELD coating, an R&D 100 Award winner.

The Laboratory, together with research and commercial partners, also received three regional awards for technology transfer from the Federal Laboratory Consortium. One award was for the development of the Intelliprobe optical breast cancer diagnostic system and a second award was for the commercialization of the dynamic transmission electron microscope. The third award recognized i-GATE (Innovation for Green Advanced Transportation Excellence), a public–private partnership that assists small businesses in developing transportation and renewable energy technologies.

Researchers inducted into LLNL's new Entrepreneurs Hall of Fame pose after receiving their commemorative plaques during the 60th anniversary celebration.

Safety, Security, and Sustainability

Demonstrating safety and security excellence and sustainable environmental stewardship in all Laboratory activities

Best practices in the areas of environment, safety, and health (ES&H) and security are implemented throughout the Laboratory, and management systems include processes for continuous improvement. The safety of employees and the public is ensured through prudent risk management coupled with active measures to prevent accidents.

The Laboratory introduced new safer bicycles for employees to use traveling around the site. The bikes are low-maintenance and equipped with an aluminum frame and airless tires.

Attention to ES&H

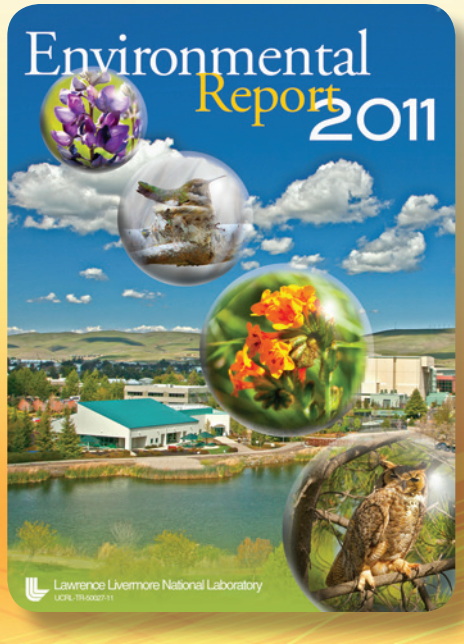
Laboratory employees' focus on safe work practices is paying off, as measured by key safety performance statistics that are now at a multidecade low. The FY2012 total recordable case (TRC) rate of 1.4 represents a 25 percent decrease from the previous year. More significantly, the days away, restricted, or transferred (DART) rate, which is a measure of the severity of injuries, is down by 48 percent (to 0.55). Attention to safety is supported by high-quality, well-documented safety management programs that hold line management responsible and accountable for safe work practices, work planning and control, and feedback and improvement. LLNL successfully completed the second inspection of its Occupational Health and Safety Assessment Series (OHSAS) 18001 accredited Safety Management System.

The latest version of LLNL's Site Annual Environmental Report documents continued findings of no adverse impact to public health or environment from Laboratory operations at the main site and Site 300 near Tracy, California. The Laboratory's Environmental Management System, which is ISO 14001 accredited, provides a systematic approach to identifying and reducing the environmental impact of Laboratory activities with strong focus on continuous improvement. The Laboratory also received a three-year recertification of its Environmental Management System.

Environment and Sustainability Awards

Through heightened employee awareness and implementation of specific actions, the Laboratory is reducing greenhouse gas emissions and energy and water usage. Steps taken in 2012 include the installation

LLNL's recently-issued Site Annual Environmental Report (for 2011) found no adverse impact to public health or environment from Laboratory operations.



With a concern for the safety of employees and neighbors, Laboratory management established a fire department in 1954. It started out with just eight firefighters responsible for protecting the Laboratory site. Pictured in 1956, the department grew over time and developed mutual aid relationships with neighbors. Laboratory firefighters are now part of the Alameda County Fire Department.

60 Years of Excellence

of cool roofs, programmable thermostats, low-flow faucets, and advanced metering of electricity and natural gas usage. While significant progress is being made, the high demands posed by today's computational and experimental facilities supporting mission-direct research are making it difficult for the Laboratory to fully achieve federal and DOE-mandated goals in energy intensity and water use.

LLNL's concerted sustainability efforts include many award-winning projects. In 2012, the NIF Operations Support Building achieved certification under the Leadership in Energy and Environmental Design (LEED) Green Building Rating System. It is the fifth building at the Laboratory to be LEED certified. LLNL also earned three Pollution Prevention Awards from NNSA for use of "green cleaning" methods and products in the NIF Class 10000 clean room and for two collaborations with Sandia National Laboratories/California—a farmers market and a hydrogen shuttle bus project. In addition, the Laboratory garnered a "Best in Class" award in Integrative Planning and Design for the HPC Innovation Center at the Livermore Valley Open Campus.

Site Security and Deinventory

LLNL efficiently and effectively maintained secure operations in FY2012. The Laboratory's Security Organization conducted a strong self-assessment program and no findings were identified in two on-site evaluations conducted by the DOE Office of Health, Safety, and Security. Security Category I/II operations were conducted in a manner compliant with DOE requirements as the Laboratory worked to remove the last of the special nuclear material items that require the highest level of protection. Deinventory of these items was completed in September 2012, two years ahead of the schedule originally planned. The Security Organization has made the transition to security Category III operations that are appropriate for the small quantity of special nuclear material that remains on site. Deinventory reduces Laboratory security costs by about $40 million per year.

Cyberdefense

Effective cyberdefense is a continuing priority. For example, in September 2012 alone, the Laboratory received 7.3 million emails of which 73 percent were spam or malicious. To strengthen protection, LLNL implemented in FY2012 major milestones in a new Risk Management Framework for cybersecurity that is being developed in conjunction with the NNSA Livermore Site Office.

In addition, a Laboratory cybersecurity expert led a multilaboratory team of collaborators, the Focused Advanced Persistent Threat group, to develop and implement a simple tool for quickly sharing information about cyberthreats. Called the Master Block List, this service and data aggregation tool was recognized at the 2012 National Cybersecurity Innovation Conference as one of the 25 top cybersecurity innovations of the year. The service allows the 10 DOE/NNSA labs and plants to share in real-time domain names that are known or suspected to be untrustworthy. These lists are used to create filters or blocks against cyberattacks.

An NNSA-award winning farmers market is conducted in partnership with Sandia National Laboratories/California, promoting a healthy work environment and supporting DOE's sustainability efforts.

The Alameda County Regional Emergency Communication Center, which is located at the Laboratory, celebrated its 10th anniversary in 2012.

Management and Operations

Guiding the Laboratory's future course, managing the workforce, improving work processes and business practices, and achieving cost efficiencies

Excellence in management, business, and operations and attention to the needs of the workforce complement LLNL's outstanding performance in S&T. Priorities include moving to a more integrated financial management system, improving the cost-effectiveness of operations, and providing a first-class workplace.

Acting Deputy Director for Science and Technology Bill Goldstein, shown speaking at Science Day, is leading a team effort to update LLNL's Science and Technology Roadmap for institutional investment.

Information Technology Improvements

LLNL upgraded its Enterprise Data Center in FY2012 by adding 40 percent more capacity and substantially enhancing its virtualization technology. The center consolidates into one location nearly 500 programmatic and business computing servers, lowering costs and increasing efficiency and reliability of data management. Seven other business systems projects, selected by the Business Systems Council, were implemented. They improve capabilities to manage work controls, track proposals for work projects, ensure continuity of operations for nuclear and radiological facilities, and monitor the status of high-level performance metrics. The Laboratory also implemented IdeaHub, an internal Web-based tool for collaboration of ideas, and is taking institution-wide steps to revamp its external Web presence. Other information technology upgrades, such as expansion of wireless access, are improving the workplace for employees and visitors.

Facility and Infrastructure Reinvestments

LLNL exceeded NNSA goals in FY2012 for high readiness and appropriate reinvestment to maintain the Laboratory's facilities and infrastructure. Mission critical facilities operated with 99.9 percent reliability and the Facility Condition Index (the ratio of deferred maintenance to replacement value) ended the year at 4.43 percent (better than the 5 percent goal). For mission dependent/not critical enduring facilities the index was also lower than NNSA's goal (8.5 percent). The new requirement for a Twenty-Five Year Site Plan submittal to NNSA has helped shape the LLNL facilities strategy. The plan provides the Laboratory with an effective venue for clearly articulating its needs for mission line item investments and infrastructure improvements to provide long-term mission support for LLNL's national security programs, as well as funding support to demolish legacy facilities.

Attention to Workforce Needs

To ensure the continuing quality of its outstanding workforce, the Laboratory provides a wide range of employee development, mentoring, and leadership training programs. Special attention was devoted to succession planning as part of an institution-wide workforce review conducted in May 2012. All organizations at the Laboratory prepared succession plans down to the division leader and program leader levels. These succession

Livermore's facility and infrastructure investment strategy balances efforts to habilitate older buildings, maintain mission-critical and mission-supporting facilities, modernize the information-technology infrastructure, develop the Livermore Valley Open Campus, and seek funding to construct new facilities.

The opening day staff of the new laboratory set up operations in the infirmary building at the abandoned Naval Air Station. It was 111 degrees in Livermore on September 2, 1952, and there was no air conditioning. By the end of 1952, the staff had grown to 300, and within just five years to 3,100. Now facilities with a replacement value of $5.67 billion house a workforce of 6,900.

60 Years of Excellence

The LLNS Board of Governors welcomes three new independent governors: Donald J. Kintzer, Ellen O. Tauscher, and Steven Koonin (see page 24).

plans are being used to inform nominations for leadership programs. Several organizations began offering a yearlong Emerging Leader Program as a result of the planning process.

The Laboratory also sponsors award-winning work–life programs that engaged over 10,000 participants in FY2012. Examples include the Author Series of speakers, Music @ the Bosque summer outdoor concerts, and the Living Well Series of lectures and activities, which was complemented by an annual Get Active Fitness Challenge that attracted a record-setting 1,315 participants this year. Nearly 650 children of employees visited the site on Take Our Daughters and Sons to Work Day, which featured a full schedule of fun educational activities.

Operations Excellence Awards

In September 2012, Director Parney Albright recognized 72 employees with Director's Institutional Operations Excellence Awards. The awards program recognizes extraordinary team efforts that benefit the overall institution, demonstrate cost savings, and improve Laboratory programs and operations. For example, an award was presented to the team that created a new travel authorization system and training materials on its use. Implemented in January 2012, the Travel Authorization Module replaces five other electronic systems and removed paper processes. Overall, more than 50 Lean Six Sigma projects were completed during the year, representing a $37 million cost savings or avoidance benefit.

LLNS Board of Governors Activities

The LLNS Board of Governors and its committees continue to provide oversight of the Laboratory in critical areas related to mission and mission-support activities.

Young visitors check out a NIF optics display during "Take Our Daughters and Sons to Work Day," one of many activities that are part of work–life programs for employees and their families.

The committees delve into their specific areas through briefings on important LLNL activities, observations of Laboratory facilities, and participation in external review committees and Functional Management Reviews (FMRs). Holding joint meetings, the LLNS and LANS Boards and committees also work to better integrate activities and make both laboratories and the NNSA enterprise more effective and efficient.

In FY2012, LLNS held seven FMRs in selected topical areas. Their feedback to improve Laboratory performance included recommendations to improve fall protection, address concerns about Laboratory time keeping, assure that pre-job briefings were effective, and better integrate sustainability practices at the three NNSA laboratories. Six directorate review committee meetings were also held. Almost 100 reviews have been conducted since 2007, resulting in more than 430 recommendations acted on by LLNL managers to improve Laboratory performance.

Community Connections

Supporting local communities through science education and charitable giving

The Laboratory is committed to being an integral and involved member of the community and, to this end, supports a wide range of activities in science outreach and education. Employees generously contribute to local communities through charitable giving and volunteer efforts. In addition, the LLNS gift program provides support to community science and math education and cultural arts.

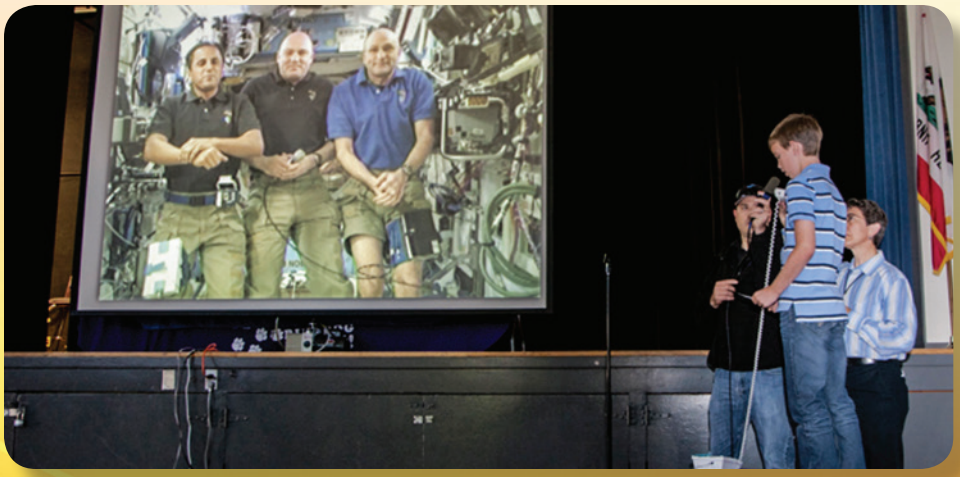
Interested students gather around one of LLNL's booths at Discovery Day at AT&T Park, the finale to the inaugural Bay Area Science Festival.

"Out of this World" Science Education

The Laboratory collaborated with the Livermore Joint Unified School District to enable students at Junction Avenue School to talk with three astronauts via an in-flight downlink from the International Space Station as part of NASA's Teaching from Space program. The entire school's student body, from kindergarten to 8th grade, assembled to watch the videoconference and ask questions of the astronauts. A former shuttle astronaut and current LLNL staff member emcee'd the event.

LLNL's Science on Saturday lecture series for middle- and high-school students again played to sold-out crowds. More than 100 current and pre-service science teachers participated in summer Teacher Research Academies at LLNL. A new academy was launched to introduce teachers to computer modeling and simulation. Technical communication workshops were added to enhance teachers' and students' skills in technical writing and presentation. The Laboratory also supported a teacher–student research partnership program where participants apply bioinformatics tools to sequence DNA samples, leading to publications in the GenBank DNA Sequence Database. This past year, more than 50 student-submitted unique gene sequences were accepted for publication in the gene database.

Students ask questions about life in space to astronauts (from left) Joseph Acaba, Andre Kuipers and Don Pettit, of Expedition 31 aboard the International Space Station.



LLNL-Sponsored Science Fair Expanded

Approximately 350 middle- and high-school students and more than 100 teachers from 60 schools participated in the inaugural Alameda County Science and Engineering Fair (ACSEF). More than 170 awards were distributed for 1st, 2nd, and 3rd place and honorable mention, and 60 special awards from national and local government and industry sponsors also were presented. This event grew out of the extremely successful Tri-Valley Science and Engineering Fair, organized for 15 years by LLNL. With its county-wide focus, the ACSEF reaches a very broad and diverse population of students and teachers and provides an avenue of scientific outreach that had previously been missing from Alameda County.

60 Years of Excellence

Livermore grew in population from 4,500 to 16,000 residents during the 1950s as Laboratory employees and their families moved in and mixed with local ranchers and vintners. Mindful of community needs, Laboratory staff members organized in 1958 to raise funds for construction of the Valley Memorial Hospital in the City of Livermore.

Lab Seismic Research on Display

LLNL science contributed to a major new exhibit at the California Academy of Sciences. "Earthquake: Life on a Dynamic Planet" takes visitors on a tour through space and time, flying over the San Andreas fault before diving into the planet's interior, traveling back in time to witness both the 1906 San Francisco earthquake and the breakup of Pangaea 200 million years ago. With an emphasis on scientifically accurate data, the show draws heavily from the expertise of key partners. The Laboratory provided accurate ground motion simulations for the 1906 earthquake, ground motions for a hypothetical earthquake on the Hayward Fault, visualizations of seismic waves traveling through the Earth, and a temperature map of Earth's interior based on imaging with seismic waves.

LLNL Featured at Major Science Festivals

The Laboratory was among many noted exhibitors participating in the inaugural Bay Area Science Festival, held in November and the second USA Science and Engineering Festival, held in April in Washington, D.C. At both events, science enthusiasts young and old flocked to LLNL booths to view a three-dimensional video about NIF and marvel at a laser "water fountain," test their knowledge with a science challenge game, try to solve the global energy crisis with an interactive climate simulation, and take part in the ever-popular Fun with Science demonstrations. The one-day Discovery Day at AT&T Park drew more than 20,000 visitors, and attendance at the three-day USA festival topped 100,000.

HOME Campaign and Community Gifts

A record-breaking $3.6 million was raised in the Laboratory's HOME (Helping Others More Effectively) Campaign, an annual charitable drive that benefits community and nonprofit agencies in the Tri-Valley, San Joaquin Valley, and greater San Francisco Bay Area. Employees pledged a total of $2,602,189, the largest amount ever raised in the campaign's 37-year history, and the Laboratory's management contractor LLNS contributed $1 million in matching funds.

At a ceremony in the downtown-Livermore LLNS office, Deputy Director Tom Gioconda presented checks totaling $100,000 to the recipients for the 2011 LLNS Community Gift Program. LLNS received 59 applications totaling more than $600,000 in requests. Twenty-two applications were selected for awards through a committee review process. The majority of these awards serve children in the Tri-Valley and San Joaquin County, with a focus on science and math education and cultural arts.

Visitors enter a major new exhibit on earthquakes at the California Academy of Sciences in San Francisco, featuring some of LLNL's seismic research and modeling.

The 2011 Run for HOME provided an opportunity for serious and not-so-serious runners and walkers to exercise, mingle, and learn more about HOME-supported charity organizations.

Workforce Recognition

Acknowledging exceptional performance and expertise

The challenges of LLNL's mission require a workforce of extremely talented and dedicated employees. The many awards and honors received by Laboratory personnel are a testament to their expertise and the importance of their work.

Tom Guilderson

Ernest Orlando Lawrence Award

Geochemist Tom Guilderson was honored with DOE's Ernest Orlando Lawrence Award. Guilderson was recognized for seminal work in climate variability and the carbon cycle. His accomplishments include groundbreaking radiocarbon measurements of corals, advancements in understanding the paleohistory of ocean currents and ocean processes revealing past climate variability, and the explanation of how physical and biogeochemical oceanic processes affect the global carbon cycle.

NNSA Science and Technology Award

Mike McCoy was honored with the first-ever NNSA Science and Technology Award for his pioneering work in high-performance computing (HPC) that established LLNL as a world-class supercomputing center. In presenting the award, NNSA Administrator Tom D'Agostino recognized McCoy's "relentless pursuit of excellence" and the global influence of his leadership in HPC.

International Council for Science

Kennedy Reed was elected to the executive board of the International Council for Science, a nongovernmental organization that aims to strengthen international science. The council has become a major entity representing science in many global policy issues, especially within the United Nations.

DOE Achievement Awards

Roger Aines, Tom Buscheck, Mark Havstad, Wayne Miller, Chris Spadaccini, and Todd Weisgraber were presented with Secretary of Energy Achievement Awards for their contributions to flow rate calculations for the Macondo Well in response to the Deepwater Horizon oil-rig disaster. Their work was conducted as part of the multilaboratory Flow Rate Technical Group/Nodal Analysis Team, laboratory Flow Rate Technical Group/Nodal Analysis Team.

DNDO Superior Performance Award

The Transformational and Applied Research Directorate of the Domestic Nuclear Detection Office presented its Superior Performance Award to Nerine Cherepy, Steve Payne, and the LLNL Scintillator Discovery Team in recognition of their achievements in developing new high-performance scintillators for neutron and gamma-ray detection.

Women's Hall of Fame

Dawn Shaughnessy was inducted into the Alameda County Women's Hall of Fame in the science category. Shaughnessy, along with her team, has discovered six new elements on the periodic table, the heaviest elements known to date (see page 12). She joins nine other current or past LLNL employees to be so honored.

Excellence in Fusion Engineering

Mike Dunne received the Fusion Power Associates' Excellence in Fusion Engineering Award. Dunne was honored for his many technical contributions to high-energy-density physics and laser facility design and operations and for his leadership of the Laboratory's LIFE (laser inertial fusion energy) project.

APS John Dawson Award

Livermore researchers Laurent Divol, Pierre Michel, Debbie Callahan, Ed Williams, Nathan Meezan, and Bob Kirkwood, together with George Kyrala

Mike McCoy

The December 1952 Laboratory phone book listed 250 employees, including a newly transferred physicist named Dick Post, who still comes to work four days each week. During his remarkable 60-year career, Post has been a leading researcher in magnetic fusion research and has worked on other important energy and transportation research, such as flywheels for energy storage. He received the Laboratory's first Lifetime Achievement Award and a congratulatory letter from Secretary of Energy Steven Chu at the 60th anniversary celebratory event.

60 Years of Excellence

of Los Alamos, were recipients of the American Physical Society (APS) John Dawson Award for Excellence in Plasma Physics Research. The award recognized the team's work on understanding laser–plasma interactions.

ANS Professional Women's Achievement Award

Susana Reyes received the American Nuclear Society's Mary Jane Oestmann Professional Women's Achievement Award for her leadership in developing detailed hazard and safety analyses for inertial and magnetic fusion facilities, including NIF and ITER, and for future power reactors.

Susana Reyes

Ascent Award

Stephen Klein was named as one of four inaugural recipients of the American Geophysical Union Atmospheric Sciences Section's Ascent Award. He was selected for his work in elucidating the role of clouds in climate change and the fidelity with which climate models can simulate clouds.

Early Career Awards

Two LLNL employees received a Presidential Early Career Award for Scientists and Engineers. Physicist Heather Whitley was chosen for her research related to the transport processes in dense plasmas, such as those found in NIF experiments. Computational scientist Jeffrey Banks was recognized for his work in computational physics and the basic mathematics needed to advance scientific simulation capabilities.

In addition, four Laboratory scientists won DOE Office of Science Early Career Research Program awards. Celine Bonfils earned the award for her work on the detection and attribution of regional climate change. Gianpaolo Carosi was selected for his work in search of dark matter axions, Andreas Kemp for large-scale modeling of intense short-pulse laser interactions, and Jaime Marian for his work in computational modeling and the design of radiation-tolerant materials for fusion environments.

From left: Andreas Kemp, Celine Bonfils, Gianpaolo Carosi, and Jaime Marian.

Heather Whitley

Jeffrey Banks

Ph.D. and Postdoctoral Awards

Four young researchers at LLNL received prestigious professional society awards. Erik Swanberg received the American Physical Society (APS) California section's Margaret Burbidge Award for the best experimental research by a graduate student. Yu-Hsin Chen was selected for the Marshall Rosenbluth Outstanding Doctoral Thesis Award by the APS Division of Plasma Physics. Frédéric Pérez received a Ph.D. Research Award from the Plasma Physics Division of the European Physical Society. Penny Wozniakiewicz was awarded the prestigious Marie Curie Fellowship by the European Commission on Research and Innovation.

Fellows

Four Laboratory scientists were honored as fellows of professional societies. David Fittinghoff and Ed Moses were elected as fellows of the Optical Society of America. John Edwards was selected as an APS fellow. Chris Barty was named a fellow of SPIE, the international society for optics and photonics.

LLNS Organization and Annual Costs

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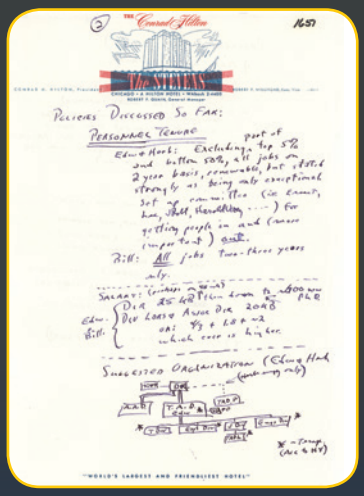
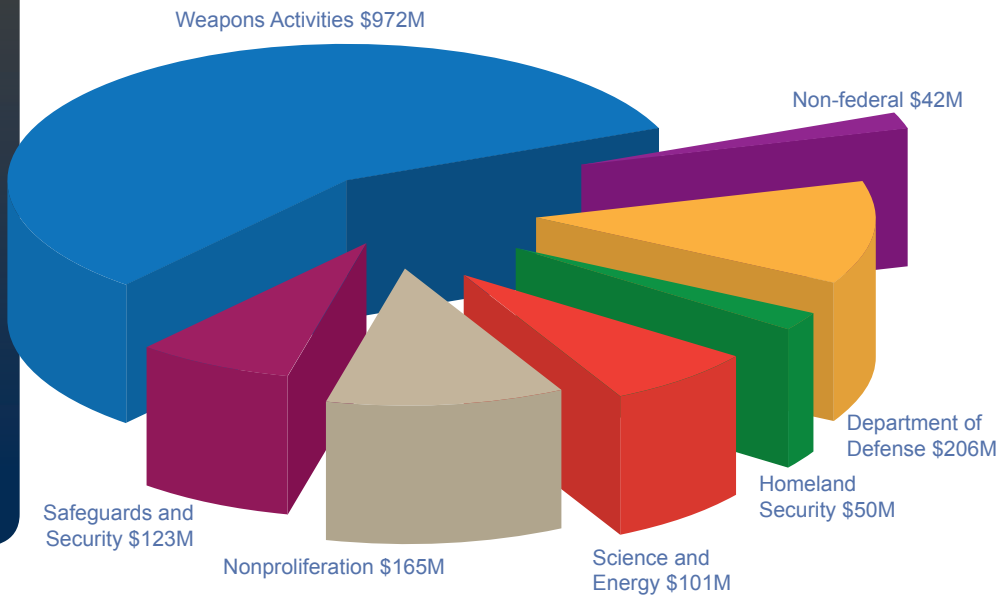
At the Board of Governors meeting in September 2012, front row left to right: John Howanitz, Craig Albert, Norman Pattiz, Richard Mies, Steven Koonin, Donald Kintzer; and back row left to right: David Walker, William Frazer, Parney Albright, Jeffrey Wadsworth, Steven Beckwith, Craig Weaver.



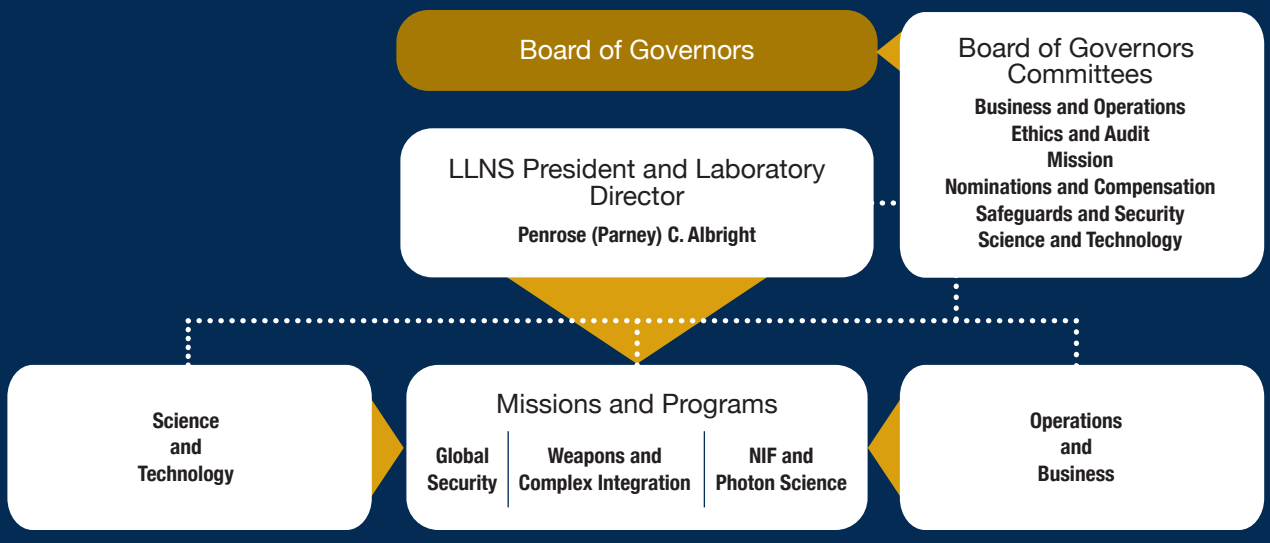
In an early set of notes written on hotel stationery, Herbert York outlines for Ernest O. Lawrence a suggested organization for the new Laboratory—focused on thermonuclear weapons research with a program on fusion energy. In early 1952, York had been tasked by Lawrence to explore the need for a new Laboratory, and then served as the first director.

60 Years of Excellence

LLNL FY2012 Actual Costs: $1.7 billion



Lawrence Livermore National Security



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Lawrence Livermore National Laboratory

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